High School Environmental Science Standards and Learning Activities

SCIENTIFIC INVESTIGATION AND INQUIRY

E.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations.

Students:

1. Know the elements of scientific methodology (identification of a problem, hypothesis formulation and prediction, performance of experimental tests, analysis of data, falsification, developing conclusions, reporting results) and be able to use a sequence of those elements to solve a problem or test a hypothesis. Also, understand the limitations of any single scientific method (sequence of elements) in solving problems.
2. Know that scientists cannot always control all conditions to obtain evidence, and when they are unable to do so for ethical or practical reasons, they try to observe as wide a range of natural occurrences as possible so as to be able to discern patterns.
3. Recognize the cumulative nature of scientific evidence.
4. Recognize the use and limitations of models and theories as scientific representations of reality.
5. Distinguish between a conjecture (guess), a hypothesis, and a theory as these terms are used in science.
6. Plan and conduct scientific investigations to explore new phenomena, to check on previous results, to verify or falsify the prediction of a theory, and to use a crucial experiment to discriminate between competing theories.
7. Use hypotheses to choose what data to pay attention to and what additional data to seek, and to guide the interpretation of the data.
8. Identify and communicate the sources of error (random and systematic) inherent in an experiment.
9. Identify discrepant results and possible sources of error or uncontrolled conditions.
10. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data. (The focus is on manual graphing, interpreting graphs, and mastery of metric measurements and units, with supplementary use of computers and electronic data gathering when appropriate.)
11. Formulate and revise explanations using logic and evidence.
12. Analyze situations and solve problems that require combining concepts from more than one topic area of science and applying these concepts.
13. Apply mathematical relationships involving linear and quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations.
14. Observe natural phenomena and analyze their location, sequence, or time intervals (e.g., relative ages of rocks and succession of species in an ecosystem).

SCIENTIFIC INVESTIGATION AND INQUIRY (CONTINUED)	
Examples	*Students conduct a field study in their local watershed, performing physical, biological, and chemical tests. Prior to the field study, students formulate a hypothesis regarding the water's quality. They identify conditions outside of their control that may affect their test findings (e.g., weather, time of day). Following the field study, students verify their findings with the DC Department of the Environment or a local monitoring organization, and create a presentation of their data, noting any deviations from the original hypothesis (E.1.1, E.1.2, E.1.9, and E.1.11).* *Students analyze the challenges of working with models to create restoration plans and discuss how model limitations affect a restoration program's results (E.1.4).* *Students design an experiment to test for acid rain, noting possible sources of error in the experiment's design (E.1.6 and E.1.8).* *Students hypothesize about the effect of weather on the salinity of the Chesapeake Bay's major tributaries. Students develop an experiment to test the hypothesis and include the details of when, where, and how the data should be sampled (E.1.7).* *Students select one issue uncovered during their field study and develop a restoration plan to address the issue (E.1.12).* *Students investigate a forest's succession pattern and visit a local park or natural area to determine whether the park is young, mature, or in its climax stage (information is available at forest.wisc.edu/extension/publications/78.pdf) (E.1.14).*

ENVIRONMENTAL SYSTEMS

E.2. Broad Concept: The environment is a system of interdependent components affected by natural phenomena and human activity. As a basis for understanding this concept,

Students:

1. Understand and explain that human beings are part of Earth's ecosystems, and that human activities can, deliberately or inadvertently, alter ecosystems.
2. Explain how environmental change in one part of the world can impact seemingly distant places and systems.
3. Describe how the global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and population growth.
4. Recognize and explain that in evolutionary change, the present arises from the materials of the past and in ways that can be explained (e.g., formation of soil from rocks and dead organic matter).

Examples	*Students select an exotic nuisance species and trace how it was introduced to the United States and its effect on the environment (e.g., zebra mussels, purple loosestrife, phragmites, and snakehead fish) (E.2.1).* *Students research the effect of polar ice cap melting and sea-level rise and its effect on coastal communities (E.2.2).* *Students research the Kyoto Protocol and perform a mock debate to determine if the United States should sign the agreement (E.2.3).*

ENVIRONMENTAL SYSTEMS (CONTINUED)
Students research the formation of the coastal plain (caused by the erosion of the Appalachian Mountains) and create a series of clay (or other material) models showing the coastal plain development over the last 100 million years (E.2.4). *Students conduct "A Rottin' Experiment" from* The Wonders of Wetlands *curriculum.* *Students compost a variety of materials in 2-liter beverage bottles and determine which conditions promote decomposition (E.2.4).*

ECOSYSTEMS
E.3. Broad Concept: Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept,
Students:
1. Explain that biodiversity is the sum total of different kinds of organisms in a given ecological community or system, and is affected by alterations of habitats.
2. Know and describe how ecosystems can be reasonably stable over hundreds or thousands of years.
3. Understand and describe that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually results in a system similar to the original one.
4. Understand and explain that ecosystems tend to have cyclic fluctuations around a state of rough equilibrium, and change results from shifts in climate, natural causes, human activity, or when a new species or nonnative species appears.
5. Know that organisms may interact in a competitive or cooperative relationship, such as producer/consumer, predator/prey, parasite/hosts, or as symbionts, and explain how these interactions contribute to the stability of an ecosystem.
6. Recognize and describe the difference between systems in equilibrium and systems in disequilibrium.
7. Explain how water, carbon, phosphorus, and nitrogen cycle between abiotic resources and organic matter in an ecosystem, and how oxygen cycles via photosynthesis and respiration. Diagram the cycling of carbon, nitrogen, phosphorus, and water in an ecosystem.
8. Describe the role of nitrogen and carbon cycles in the improvement of soils for agriculture.
9. Locate, identify, and explain the role of the major Earth biomes (e.g., grasslands, rainforests, arctic tundra, deserts) and discuss how the abiotic and biotic factors interact within these ecosystems.
10. Explain the process of succession, both primary and secondary, in terrestrial and aquatic ecosystems.
11. Describe how adaptations in physical structure or behavior may improve an organism's chance for survival and impact an ecosystem.
12. Describe the concepts of niche and habitat, and explain the effects of loss of habitat on a species' survivability.
13. Explain how soil, water, and pest management are achieved in various agricultural systems (conventional and organic). Describe the tenets of sustainable agriculture.

ECOSYSTEMS (CONTINUED)	
Examples	*Students conduct biological monitoring studies (macroinvertebrate sampling) in a local waterway and determine the taxa richness and its index of biological integrity (E.3.1).* *Students visit the USDA – Forest Service and the National Park Service Web sites to learn the current costs and benefits associated with forest fires and how some vegetation has adapted to survive in fire-prone environments (E.3.3).* *Students create informational flyers detailing the economic costs and effects of an invasive species found locally and offer suggestions to slow the spread of the species (E.3.4).* *Students create a three-dimensional display of locally found macroinvertebrates, highlighting physical adaptations, and their relationship to each other (e.g., predator/prey producer/consumer, etc.) (E.3.5 and E.3.11).* *Students determine the relationship between nutrients, algal blooms, and eutrophication and the Chesapeake Bay's yearly "dead" or anoxic zones (E.3.6).* *Students compare several brands of fertilizer for their recommended applications and compare the different application recommendations for different plant types (E.3.8).* *Students compare the variety of bird species found in downtown DC versus Rock Creek Park and the habitat needs of each species (E.3.12).* *Students visit an organic farm (e.g., Accokeek Foundation-National Colonial Farm) or an organic market/supermarket and interview the farmer or produce manager to compare and contrast the difference between conventional and organic farming (E.3.13).*

POPULATIONS	
E.4. Broad Concept: The amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle organic materials from the remains of dead organisms. As a basis for understanding this concept,	
Students:	
1. Explain the concept of carrying capacity.	
2. Demonstrate how resources, such as food supply, the availability of water, and shelter, influence populations.	
3. Demonstrate and explain how fluctuations in population size and population growth rates are determined by such factors as birth rate, death rate, and migration rate.	
4. Describe the effect of overpopulation (i.e., resource depletion and potential elimination of species), the role of predators in maintaining ecosystem stability, and methods of population management.	
5. Describe current and historical trends in human population growth in different regions of the world.	
6. Explain how the size and rate of growth of the human population in any location is affected by economic, political, religious, technological, and environmental factors.	
Examples	*Students compare the ecological footprint of several countries to the United States, as well as the footprints of developed versus undeveloped countries. Students calculate their own ecological footprint and develop options to lessen their footprint (information is available at www.myfootprint.org) (E.4.1 and E.4.2).*

POPULATIONS (CONTINUED)

Students conduct a "Food for Thought" activity. Students separate into ambassador delegations that must explain their country's current population status and future projected growth to the group. Each delegation creates policies to handle the resource needs of the different countries (E.4.3 and E.4.5).

Students debate the pros and cons of re-introducing the gray wolf to Yellowstone Park and determine the value of this predator to the ecosystem (E.4.4).

Students analyze the factors guiding the location of the Chesapeake Bay Watershed's major cities — Baltimore, MD; Annapolis, MD; Washington, DC; and Richmond, VA.

Students focus on the transportation methods used during the time of settlement, the location of the falls, the effects of the cities' placement on the environment, and population centers today (E.4.6).

Students create a graphic depicting the population centers during the early 1700s, 1800s, 1900s, and today, with the final depiction showing the projected migration patterns of U.S. citizens in the next 50 years (E.4.6).

NATURAL RESOURCES

E.5. Broad Concept: Numerous Earth resources are used to sustain human affairs. The abundance and accessibility of these resources can influence their use. As a basis for understanding this concept,

Students:

1. Recognize that the Earth's resources for humans, such as fresh water, air, arable soil, and trees, are finite. Explain how these resources can be conserved through reduction, recycling, and reuse.
2. Differentiate between renewable and nonrenewable resources (including sources of energy), and compare and contrast the pros and cons of using nonrenewable resources.
3. Give examples of the various forms and uses of fossil fuels and nuclear energy in our society, and describe alternative sources of energy provided by water, the atmosphere, and the sun.
4. Demonstrate knowledge of the distribution of natural resources in the United States and the world, and explain how natural resources influence relationships among nations.
5. Recognize and describe the role of natural resources in providing the raw materials for an industrial society.
6. Analyze the trade-offs among different fuels, such as how energy use contributes to the rising standard of living in the industrially developing nations, yet also leads to more rapid depletion of Earth's energy resources and to increased environmental risks associated with the use of fossil and nuclear fuels.
7. Identify specific tools and technologies used to adapt and alter environments and natural resources to meet human physical and cultural needs.
8. Understand and describe the concept of integrated natural resource management and the values of managing natural resources as an ecological unit.

NATURAL RESOURCES (CONTINUED)	
Examples	*Students interview DC's recycling coordinator and develop suggestions for improvements in their school's waste reduction and recycling (E.5.1).* *Students visit one of the green roofs in DC (e.g., Casey Trees Building at 1425 K St., NW). They create a building plan utilizing low-impact development practices (e.g., green roofs, rain barrels, pervious pavement, composting toilets, and solar panels) (E.5.2, E.5.3, and E.5.7).* *Students highlight on a global map the top exporters of oil to the United States and then research those countries on the State Department's Web site, as well as other sources, to determine their relationship with the United States and the stability of that relationship (information is available at www.state.gov) (E.5.4).* *Students create a list of resources and the quantity they use in one day (e.g., water equals 5 gallons/toilet flush; gasoline equals 2 gallons/30 miles of driving per day) and determine personal actions they can take to conserve resources or substitute renewable resources (E.5.2 and E.5.5).* *Students review the protocol for creating an integrated natural resource management plan and create one for their ecosystem of choice (E.5.8).*

WATERSHEDS AND WETLANDS
E.6. Broad Concept: Water is continually being recycled by the hydrologic cycle through the watersheds, oceans, and the atmosphere by processes such as evaporation, condensation, precipitation runoff, and infiltration. This life-giving cycle is continually and increasingly impacted by human affairs. As a basis for understanding this concept,
Students:
1. Compare and contrast the processes of the hydrologic cycle, including evaporation, condensation, precipitation, surface runoff and groundwater percolation, infiltration, and transpiration.
2. Describe the physical characteristics of wetlands and watersheds and explain how water flows into and through a watershed (e.g., precipitation, aquifers, wells, porosity, permeability, water table, capillary water, and runoff).
3. Describe how wetlands store excess water and filter sediments and excess nutrients.
4. Examine the dynamics of diverse ecosystems in watersheds and wetlands. Identify various organisms found in Potomac River wetlands and watersheds.
5. Describe the causes of, and the efforts to control, erosion in the Chesapeake Bay.
6. Investigate and describe how point and nonpoint source pollution can affect the health of a bay's watershed and wetlands.
7. Collect, record, and interpret data from physical, chemical, and biological sources to evaluate the health of the Chesapeake Bay watershed and wetlands, and describe how the Bay supports a wide variety of plant and animal life that interact with other living and nonliving things.
8. Explain the dynamics of oceanic currents, including upwelling, density, and deep water currents, the local Labrador Current and the Gulf Stream, and their relationship to global circulation within the marine environment and climate.

WATERSHEDS AND WETLANDS (CONTINUED)	
Examples	*Students create a terrarium to observe the hydrologic cycle (E.6.1).* *Students make observations following precipitation events on their school grounds noting differences in areas where there are signs of runoff versus areas where there are no indications of runoff (E.6.2).* *Students compare the movement of water through different substrates (e.g., clay, topsoil, and sand), using the procedures outlined in the "How Thirsty Is the Ground" activity in* The Wonders of Wetlands *curriculum (E.6.2).* *Students determine the address of their local watershed using the EPA's Web site, "Surf Your Watershed" (site is at www.epa.gov/surf) (E.6.4).* *Students visit Anacostia Park's Aquatic Resource Education Center, operated by DC Fisheries, to learn about the Potomac and Anacostia Rivers' ecosystems and fish species (E.6.4).* *Students analyze satellite images of the Chesapeake Bay watershed, noting the land use of areas where there is visible erosion versus areas where there is not visible erosion following rain events (E.6.5).* *Students create a global map depicting the major ocean currents (E.6.8).*

ENERGY IN THE EARTH SYSTEM

E.7. Broad Concept: Energy and matter have multiple forms and can be changed from one form to another. As a basis for understanding this concept,

Students:

1. Explain that energy cannot be created or destroyed; however, in many processes energy is transformed into the microscopic form called *heat energy,* that is, the energy of the disordered motion of atoms.
2. Explain the meaning of radiation, convection, and conduction (three mechanisms by which heat is transferred to, through, and out of the Earth's system).
3. Understand and describe how layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. Recognize that by burning these fossil fuels, people are passing stored energy back into the environment as heat and releasing large amounts of carbon dioxide.
4. Describe how the energy derived from the sun is used by green plants to produce chemical energy in the form of sugars (photosynthesis), and this energy is transferred along a food chain from producers (plants) to consumers to decomposers.
5. Illustrate the flow of energy through various trophic levels of food chains and food webs within an ecosystem. Describe how each link in a food web stores some energy in newly made structures and how much of the energy is dissipated into the environment as heat. Understand that a continual input of energy from sunlight is needed to keep the process going.
6. Describe how the chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways.

ENERGY IN THE EARTH SYSTEM (CONTINUED)	
Examples	*Students determine how much of the sun's energy reaches the Earth and what happens to that energy once it reaches the Earth's atmosphere (E.7.2).* *Students create a timeline explaining the creation of coal (E.7.3).* *Students research their local power company and determine where and how their electricity is generated (E.7.3).* *Students simulate the formation of coal in an aquarium using sand, plant material, and soil (activity found at www.teachcoal.org/lessonplans/) (E.7.3).* *Students create a food web with locally found plants, macroinvertebrates, fish, and other organisms (E.7.4 and E.7.5).* *Students depict the carbon or nitrogen cycles, noting each recombination of the molecules throughout the cycles (E.7.6).*

ENVIRONMENTAL QUALITY

E.8. Broad Concept: Environmental quality is linked to natural and human-induced hazards, and the ability of science and technology to meet local, national, and global challenges. As a basis for understanding this concept,

Students:

1. Differentiate between natural pollution and pollution caused by humans, and give examples of each.
2. Describe sources of air and water pollution, and explain how air and water quality impact wildlife, vegetation, and human health.
3. Describe the historical and current methods of water management and recycling, including the waste treatment practices of landfills, incineration, reuse/recycle, and source reduction.
4. Understand and explain that waste management includes considerations of quantity, safety, degradability, and cost.
5. Compare and contrast the beneficial and harmful effects of an environmental stressor, such as herbicides and pesticides, on plants and animals. Give examples of secondary effects on other environmental components such as humans, water quality, and wildlife.
6. Identify natural Earth hazards, such as earthquakes and hurricanes, and identify the regions in which they occur, as well as the short-term and long-term effects on the environment and on people.
7. Recognize and describe important legislation enacted to protect environmental quality, such as the Clean Air Act and the Clean Water Act.

Examples

Students visit the EPA's Total Maximum Daily Load site and identify the local impaired waterways in the DC metropolitan area. Students highlight the waterways on a map, hypothesizing the pollutants' sources, and if they are natural or human caused (e.g., high fecal coliform levels are due to human and wildlife sources) (information source is at oaspub.epa.gov/waters/) (E.8.1).

Students research the sources of the pollutants causing Anacostia River's unusually high cancerous rate among its bottom-dwelling fish (E.8.2).

ENVIRONMENTAL QUALITY (CONTINUED)
Students interview their school's waste management company to determine where their school's trash goes once it is collected (E.8.3 and E.8.4).
Students research the story of the bald eagle and the effects of DDT on its population (E.8.5).
Students investigate the effect of Hurricane Katrina on Louisiana's wetlands. Students create a before-and-after three-dimensional model of the coastal region. Within the "after" model, they include suggestions for wetland restoration projects in the future (E.8.6).
Students select an animal located in their watershed and create a presentation exploring how the Clean Water Act affected their animals (E.8.7).
Students perform a "Give Wildlife a Break: Change the Law" activity from the Project Wet *curriculum, exploring the process of amending the Endangered Species Act (E.8.7).*
Students perform "The Law: Before and After" activity from the Project Wet *curriculum to analyze how issues and events can lead to laws and regulations (E.8.7).*